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POWER MANAGEMENT

Description

The SC250 is a synchronous step-down converter designed specifically for use as an adaptive voltage supply for CDMA and WCDMA RF Power Amplifiers (PAs). The output voltage can be adjusted dynamically between 0.3V and (Vin - 0.4)V through a linear analog control input. For high power operation, a maximum control input signal level forces the device into bypass mode where the input is connected directly to the output via an internal P-Channel pass transistor. Bypass mode also occurs when the output load demands duty cycles in excess of the maximum rated duty cycle.

The SC250 also provides an LDO regulator which can be used to supply a 2.85V bias to the PA. The internal clock runs at 1MHz to maximize efficiency while still allowing the use of small surface mount inductors and capacitors can be used.

The peak current rating of the internal PMOS switch allows a DC output current of 600mA. The bypass PMOS current rating allows a minimum of 1A DC output current in the bypass mode. Shutdown turns off all the control circuitry to achieve a typical shutdown current of 0.1µA.

Features

◆ Adjustable output voltage range — 0.3 to 3.6V
◆ Linearly proportional V_{DAC} to V_{OUT} relationship for increased PA efficiency
◆ Pass-through mode automatic and on demand
◆ Input voltage range — 2.7V to 5V
◆ Typical settling time — 40µs
◆ Output current capability — 600mA
◆ Maximum output current in bypass mode — 1A
◆ Up to 96% efficiency
◆ Constant frequency operation — 1MHz
◆ Less than 1µA shutdown current
◆ Internal 75mΩ PMOS bypass transistor
◆ PA bias voltage supply — 2.85V, 20mA, 1.5%
◆ MLPD-W8, 2.3 x 2.3mm package

Applications

◆ CDMA and WCDMA Phones
◆ Handheld Radios
◆ RF PC Cards
◆ Battery Powered RF Devices

Typical Application Circuit

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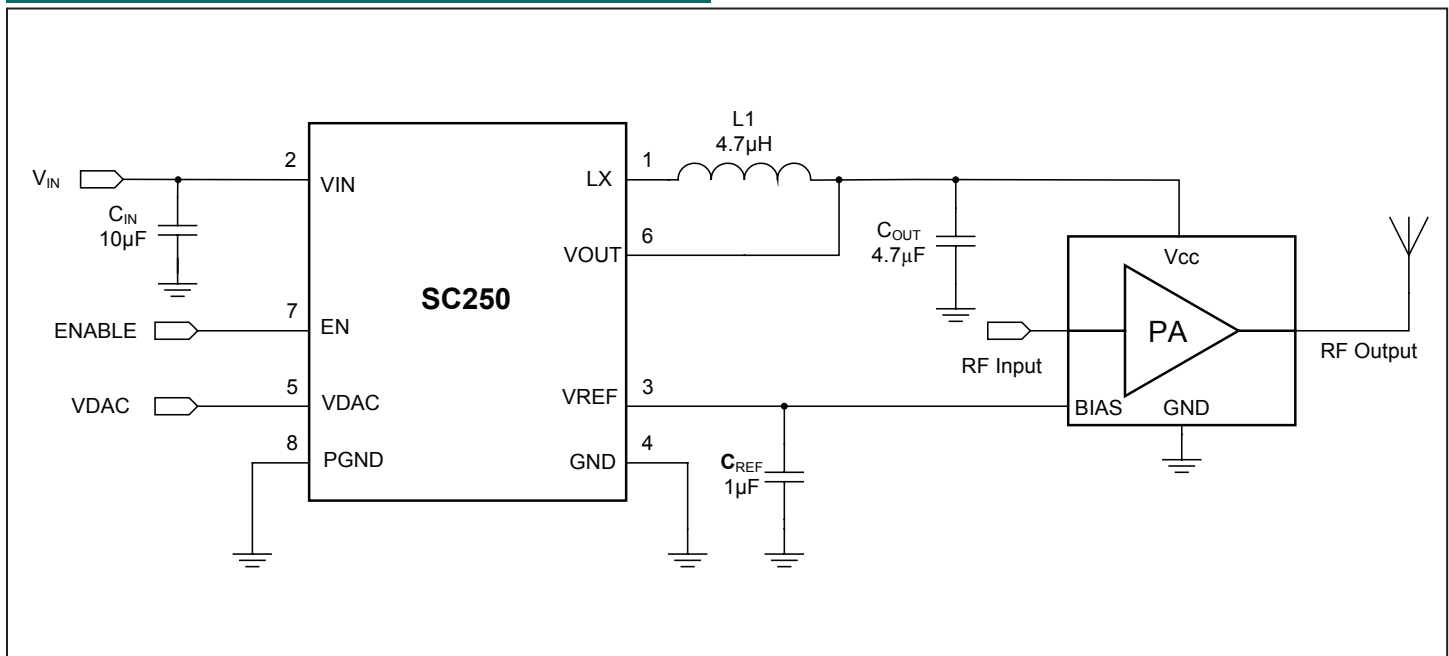
POWER MANAGEMENT

Absolute Maximum Ratings

Exceeding the specifications below may result in permanent damage to the device or device malfunction. Operation outside of the parameters specified in the Electrical Characteristics section is not recommended.

Parameter	Symbol	Maximum	Units
Input Supply Voltage	V_{IN}	-0.3 to 7	V
EN and VDAC Inputs	V_{EN}, V_{DAC}	-0.3 to 7	V
LX Pin Voltage (Power switch OFF)	V_{LX}	-1 to V_{IN} + 1, 7V MAX	V
VOUT Voltage	V_{OUT}	-0.3 to 7	V
VOUT Short Circuit to GND duration	t_{SC}	Continuous	s
Thermal Impedance Junction to Ambient [1]	θ_{JA}	110	°C/W
Operating Ambient Temperature Range	T_A	-40 to +85	°C
Junction Temperature	T_{JC}	+150	°C
Storage Temperature	T_S	-60 to +160	°C
Peak IR Reflow Temperature	T_P	260	°C
ESD Protection Level [2]	V_{ESD}	2	kV

Note:
1) Calculated from package in still air, mounted to 3" x 4.5", 4 layer FR4 PCB with thermal vias under the exposed pad per JESD51 standards.
2) Tested according to JEDEC standard JESD22-A114-B.

Electrical Characteristics

Unless otherwise noted: V_{IN} = V_{EN} =3.6V, T_A = -40 to 85°C. Typical values are at T_A = +25°C.

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Input Voltage Range	V_{IN}		2.7		5.0	V
V_{OUT} Accuracy	V_{OUT}	V_{IN} = 4V, V_{DAC} = 0.1V, I_{OUT} = 0.3A	0.25	0.3	0.35	V
		V_{IN} = 4V, V_{DAC} = 1.1V, I_{OUT} = 0.3A	3.23	3.3	3.37	V
V_{OUT} Line Regulation	$V_{OUT\ LINE}$	V_{IN} = 2.7V to 5.0V, V_{DAC} = 0.7V			0.4	%/V
V_{OUT} Load Regulation	$V_{OUT\ LOAD}$	I_{OUT} = 0A to 600 mA, V_{DAC} = 0.7V		-0.7		%
V_{REF} Accuracy	V_{REF}	I_{REF} = 10 mA	2.8	2.85	2.9	V
V_{REF} Line Regulation	$V_{REF\ LINE}$	I_{REF} = 1 mA, I_{OUT} = 0A			0.3	%/V
V_{REF} Load Regulation	$V_{REF\ LOAD}$	I_{REF} = 0.1 to 20 mA		-0.5		%
V_{REF} Load Current	I_{REF}				20	mA
Peak Inductor Current	$I_{LX\ PK}$		0.8		1.5	A
Bypass FET Current Limit	I_{PASS}		1		2.5	A

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Electrical Characteristics (Cont.)

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Quiescent Current	I_Q	Normal Mode ($V_{DAC} < 1V$)		1.5		mA
		Bypass Mode ($V_{DAC} > 1.4V$)		1		
Shutdown Current	I_{SD}	LX = open, EN = GND, V_{OUT} = open, T_A = 25°C		0.1	1	µA
VDAC Regulated Output Mode	V_{DAC}	V_{IN} = 4.2V	0.10		1.20	V
VDAC Pass-Through Mode Threshold	$V_{DAC\,PT}$	V_{DAC} Rising	1.28		1.37	V
		V_{DAC} Falling	1.20		1.3	
VDAC to VOUT Transfer Ratio	G_V			3		V/V
$R_{DS\,ON}$ of Bypass P-Channel FET	R_{PASS}	I_{OUT} = 100mA, V_{IN} = 3V, V_{DAC} = 1.4V		75		mΩ
$R_{DS\,ON}$ of P-Channel Switching FET	R_{DSP}	I_{OUT} = 100mA, V_{IN} = 3V		400		mΩ
$R_{DS\,ON}$ of N-Channel Switching FET	R_{DSN}	I_{OUT} = 100mA, V_{IN} = 3V		250		mΩ
LX Leakage Current PMOS	I_{LXP}	V_{IN} = 3.6V, LX = 0V, EN = GND			2	µA
LX Leakage Current NMOS	I_{LXN}	V_{IN} = 3.6V, LX = 3.6V, EN = GND			2	µA
VOUT Pin Bypass PMOS Leakage	I_{LVOUT}	V_{IN} = 3.6V, V_{OUT} = 0V, EN = GND			2	µA
Oscillator Frequency (Fixed Frequency)	f_{OSC}	$V_{DAC} > 0.2V$	0.85	1	1.15	MHz
Oscillator Frequency (Variable Frequency)	f_{OSCV}	V_{DAC} = 0.1V	0.65			MHz
Logic Input High	V_{IH}		1.6			V
Logic Input Low	V_{IL}				0.6	V
Control Input Current - High	I_{IH}	VDAC/EN = 3.6V			±2	µA
Control Input Current - Low	I_{IL}	VDAC/EN = GND			±2	µA
Enable Transient Over/Undershoot	OS_{EN}			20		%
Enable Transient Settling Time	t_{EN-ST}			40		µs
VDAC Transient Over/Undershoot	OS_{VDAC}			20		%
VDAC Transient Settling Time	$t_{VDAC-ST}$			40		µs

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Electrical Characteristics (Cont.)

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Pass-Through Transition Over/Undershoot	OS_{PASS}			20		%
Pass-Through Transition Settling Time	$t_{PASS-ST}$			40		µs
Thermal Shutdown	T_{SD}			160		°C
Thermal Shutdown Hysteresis	T_{SDH}			15		°C
Auto Pass-Through Threshold (V_{IN}-V_{OUT})	PT_{TH}		400	430	460	mV
Auto Pass-Through Threshold Hysteresis	PT_{TH_HYST}		135	160	190	mV

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Pin Configuration

TOP VIEW

1	LX		8	PGND
2	VIN		7	EN
3	VREF		6	VOUT
4	GND		5	VDAC
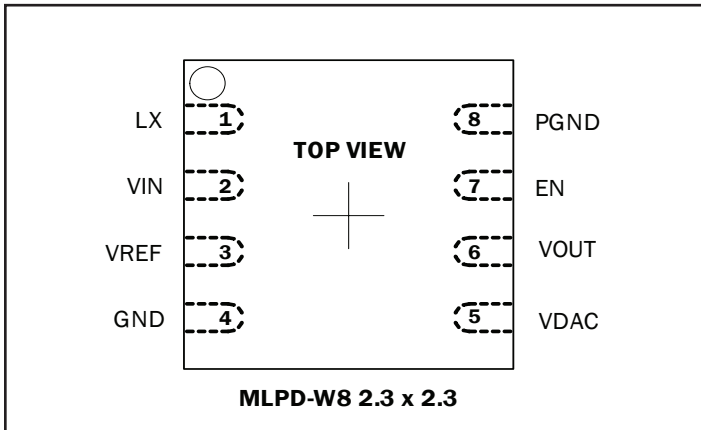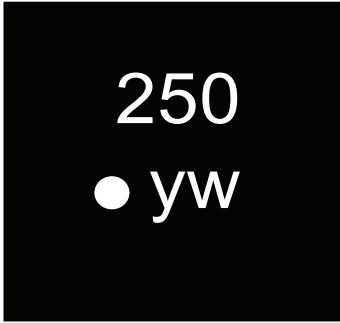
MLPD-W8 2.3 x 2.3

Ordering Information

DEVICE	PACKAGE
SC250WLTRT[1][2]	MLPD-W8 2.3x2.3
SC250EVB	Evaluation Board

Note:
1) Available on tape and reel only. A reel contains 3000 devices.
2) Device is WEEE and RoHS compliant.

Marking Information

250
● yw

Marking for the 2.3 x 2.3mm MLPD 8 Lead Package:
ww = Datecode (Reference Package Marking Design
Guidelines, Appendix A)

Block Diagram

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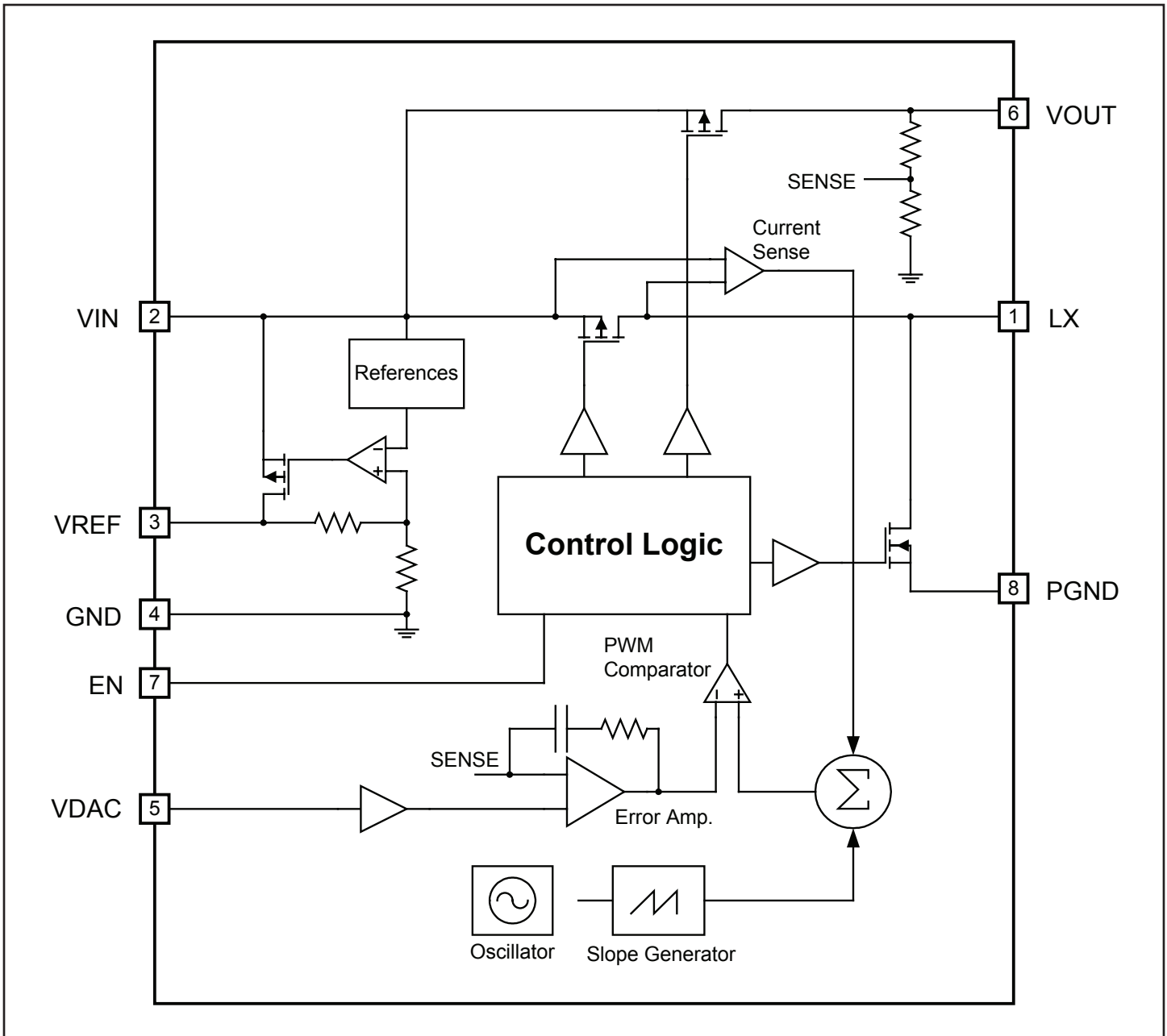
Pin Descriptions

Pin #	Pin Name	Pin Function
1	LX	Inductor connection to the switching FETs
2	VIN	Input voltage connection
3	VREF	2.85V, 20mA reference supply — can be used as a supply for power amplifier bias inputs or to supply a resistive divider on V_{DAC} to set a fixed level of V_{OUT}.
4	GND	Ground connection
5	VDAC	Analog control voltage input ranges between 0.1 and 1.2V for control of V_{OUT} in accordance with the $V_{OUT} = 3 \times V_{DAC}$ transfer function. $V_{DAC} > 1.4V$ enables pass-through mode using the internal pass MOSFET.
6	VOUT	Regulated output voltage and feedback
7	EN	Enable digital input: a high input enables the SC250, a low disables the output and reduces quiescent current to less than 1µA and LX becomes high impedance.
8	PGND	Ground reference for internal N-channel MOSFET

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Applications Information

SC250 Detailed Description

The SC250 adaptive power controller is a step-down, fixed frequency pulse-width modulated DC-DC converter designed for use with RF Power Amplifiers (PAs) in CDMA and WCDMA handsets and modules. The SC250 output is used to supply DC power to the PA rather than connecting the DC input pin directly to the battery supply. A substantial system power efficiency improvement can be achieved by allowing the system controller to adaptively adjust the DC power to the PA, reducing the total power consumption of the device when in low-power mode. To improve efficiency at all RF output gain settings, the PA supply voltage is adjusted in a linear fashion, minimizing PA supply headroom and losses.

A consequence of using the SC250 to power the PA, rather than using a linear regulator or direct connection to the battery, is that less current is needed. Reduced current consumption results in more talk-time for the handset.

Operation Modes

The SC250 output voltage is dependent on the V_{DAC} analog control voltage, defined by the following relationship:

$$V_{OUT} = 3 \times V_{DAC}$$

In a typical PA system application, the system controller determines what output power level is needed from the PA and adjusts the VDAC voltage to match the required PA headroom for optimized efficiency.

Pass-Through Mode

When the VDAC voltage reaches 1.36V, the SC250 enters pass-through mode. If the demanded output voltage is within 430mV of the input voltage, the SC250 automatically enters pass-through as this exceeds the maximum controlled duty cycle of the power converter. In pass-through mode, the device enables an internal P-Channel MOSFET that bypasses the converter, connecting the output directly to the input. The R_{DSON} of this FET is extremely low, so there is little voltage drop across the part. Pass-through allows the lowest insertion loss possible between V_{IN} and V_{OUT} under high-power conditions, thereby maintaining maximum efficiency under these conditions.

Bias Supply Output

In addition to the main output, the SC250 also provides a low current LDO output that can be used as a bias supply for power amplifiers. This output provides a regulated 2.85V with output current capability up to 20mA. The 2.85V output is guaranteed for input supply voltages in excess of 2.95V.

Protection Features

The SC250 provides the following protection features:

- Thermal shutdown
- Current limit
- Under-voltage lockout

Thermal Shutdown

The device has a thermal shutdown feature to protect the device if the junction temperature exceeds 150°C. In thermal shutdown, the PWM drive is disabled, effectively tri-stating the LX output. The device will not be enabled again until the temperature reduces by 10°C.

Short-Circuit Protection

The PMOS and NMOS power devices of the buck switcher stage are protected by current limit functions. In the case of a short to ground on the output, the LX pin will switch with minimum duty cycle. The duty cycle is short enough to allow the inductor to discharge during each cycle, thereby preventing the inductor current from "staircasing."

The pass-through PMOS is also protected by a current limit function. When the part is first enabled in pass-through, the output capacitor charges up with a large surge current. This surge current is internally limited for protection purposes, but the limit is set high enough to meet fast start-up times. In order to protect against a short-circuit condition and to allow the transient response time, an internal timer allows the part to operate under current limit conditions for a maximum of 64 cycles of the internal clock (1MHz typical). If the short-circuit conditions persists, the pass-through PMOS will turn off for 1ms, after which the first timer is restarted. This allows the part to manage thermal dissipation while giving it the ability to recover when the fault condition is removed.

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Applications Information (Cont.)

Under-Voltage Lockout

Under-voltage lockout protection is used to prevent erroneous operation. As the input decreases, the device shuts down when the voltage drops below 2.35V and will not restart until the input voltage exceeds approximately 2.5V.

Inductor Selection

The SC250 is designed for use with a 4.7µH inductor. The magnitude of the inductor current ripple is dependent on the inductor value and can be determined by the following equation:

$$\Delta I_L = \frac{V_{OUT}\left(1 - \dfrac{V_{OUT}}{V_{IN}}\right)}{L \times f_{osc}}$$

This equation demonstrates the relationship between input voltage, output voltage, and inductor ripple current.

The inductor should have a low DC resistance to minimize the conduction losses and maximize efficiency. As a minimum requirement, the DC current rating of the inductor should be equal to the maximum load current plus half of the inductor current ripple as shown by the following equation:

$$I_{LPK} = I_{OUT(MAX)} + \frac{\Delta I_L}{2}$$

Final inductor selection depends on various design considerations such as efficiency, EMI, size, and cost. Table 1 lists the manufacturers of practical inductor options.

Table 1 — Recommended Inductors

Manufacturer/Part #	Value (µH)	DCR (Ω)	Saturation Current (A)	Tolerance (%)	Dimensions LxWxH (mm)
BI Technologies HM66304R7	4.7	0.072	1.32	20	4.7 × 4.7 ×3.0
Coilcraft D01608C-472ML	4.7	0.09	1.5	20	6.6 × 4.5 ×3.0
TDK VLCF4018T- 4R7N1R0-2	4.7	0.101	1.07	30	4.3 × 4.0 ×1.8

C_IN Selection

The source input current to a buck converter is non-continuous. To prevent large input voltage ripple, a low ESR ceramic capacitor is required. A minimum value of 10µF should be used for sufficient input voltage filtering and a 22µF should be used for improved input voltage filtering.

C_OUT Selection

The internal compensation is designed to work with a certain output filter corner frequency defined by the equation:

$$f_c = \frac{1}{2\pi\sqrt{L \times C_{OUT}}}$$

This single pole filter is designed to operate with an output capacitor value of 4.7µF.

Output voltage ripple is a combination of the voltage ripple from the inductor current charging and discharging the output capacitor, and the voltage created from the inductor current ripple through the output capacitor ESR. Selecting an output capacitor with a low ESR will reduce the output voltage ripple component that is dependent upon this ESR, as can be seen in the following equation:

$$\Delta V_{OUT(ESR)} = \Delta I_{L(ripple)} \times ESR_{(COUT)}$$

Capacitors with X7R or X5R ceramic dielectric are strongly recommended for their low ESR and superior temperature and voltage characteristics. Y5V capacitors should not be used as their temperature coefficients make them unsuitable for this application. Table 2 lists the manufacturers of recommended capacitor options.

Table 2 — Recommended Capacitors

Manufacturer/Part Number	Value (µF)	Rated Voltage (VDC)	Type	Case Size
Murata GRM21BR60J226ME39L	22	6.3	X5R	0805
Murata GRM188R60J106MKE19	10	6.3	X5R	0603
TDK C2012X5R0J106K	10	6.3	X5R	0603
Murata GRM188R60J475KE19D	4.7	6.3	X5R	0603

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Applications Information (Cont.)

PCB Layout Considerations

Poor layout can degrade the performance of the DC-DC converter and can be a contributory factor in EMI problems, ground bounce and resistive voltage losses. Poor regulation and instability can result.

A few simple design rules can be implemented to ensure good layout:

1. Place the inductor and filter capacitors as close to the device as possible and use short wide traces between the power components.
2. Route the output voltage feedback and V_{DAC} path away from inductor and LX node to minimize noise and magnetic interference.

3. Maximize ground metal on component side to improve the return connection and thermal dissipation. Separation between the LX node and GND should be maintained to avoid coupling of switching noise to the ground plane.
4. To further reduce noise interference on sensitive circuit nodes, use a ground plane with several vias connecting to the component side ground.

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Typical Characteristics
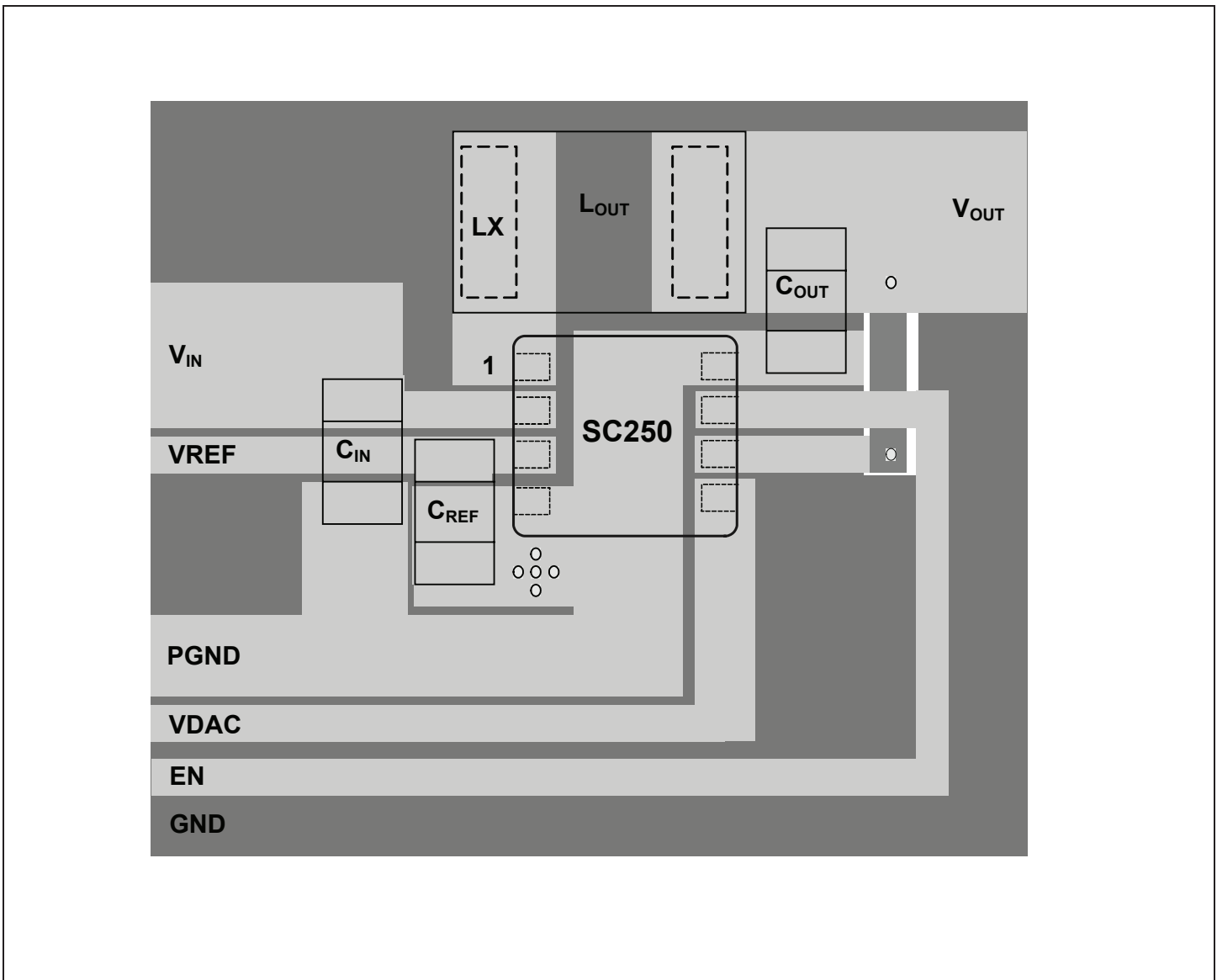
Efficiency vs. Load Current V$_{OUT}$ = 3.2V
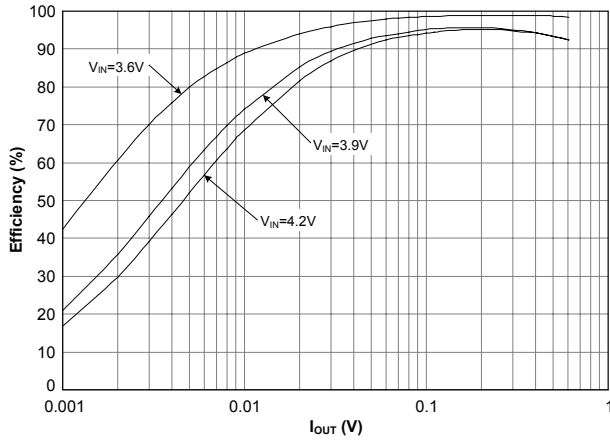
Efficiency vs. Load Current V$_{OUT}$ = 2.5V
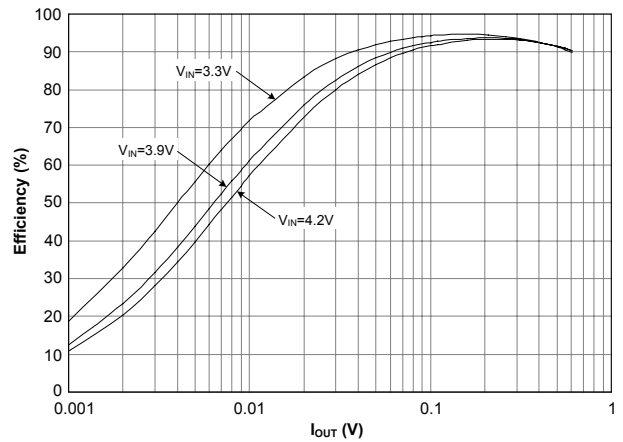
Efficiency vs. Load Current V$_{OUT}$ = 1.5V
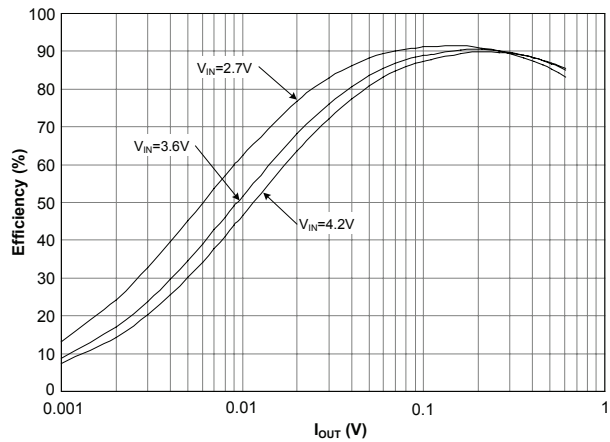
Efficiency vs. Load Current V$_{OUT}$ = 1.2V
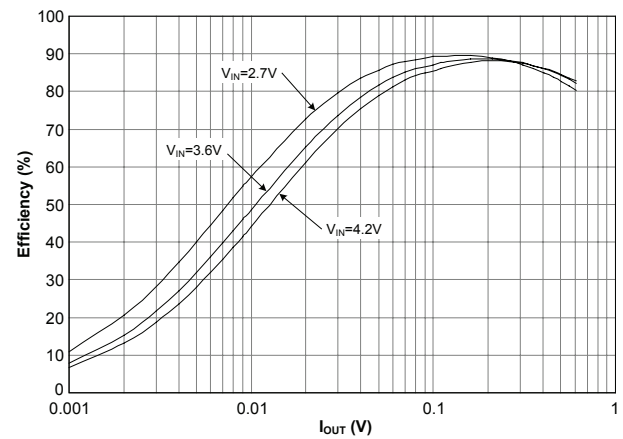
Efficiency vs. V$_{IN}$
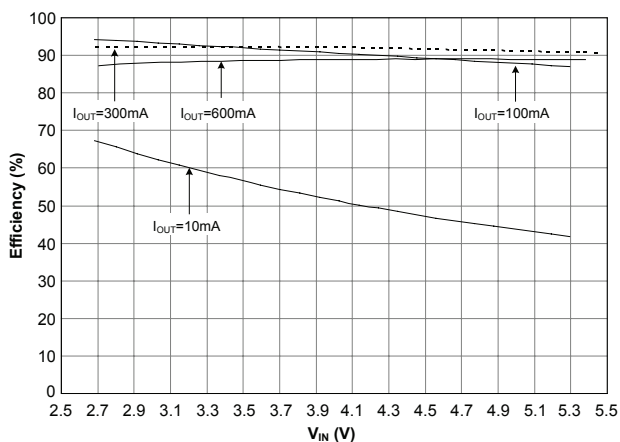
Efficiency vs. V$_{OUT}$, V$_{IN}$ = 3.6V

POWER MANAGEMENT

Typical Characteristics (Cont.)
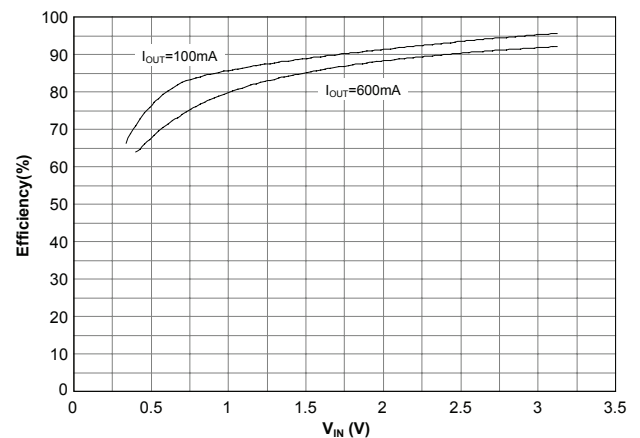
Control Transfer Function I_{OUT} = 0.3A
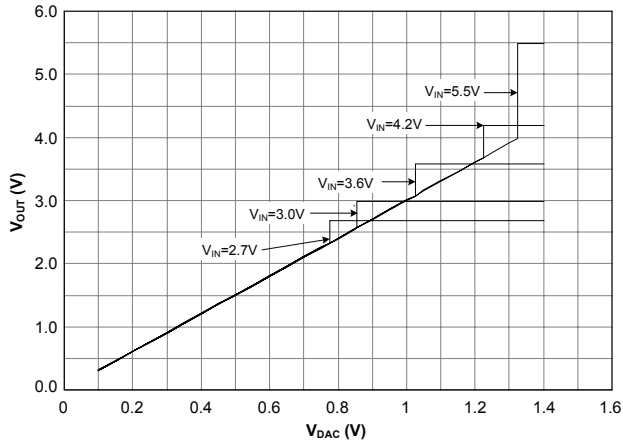
Auto Bypass Function, V_{OUT} = 3.25V
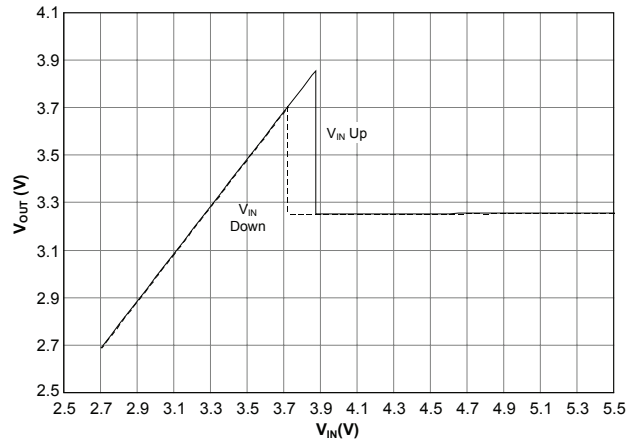
Dynamic Supply Current vs. V_{IN}
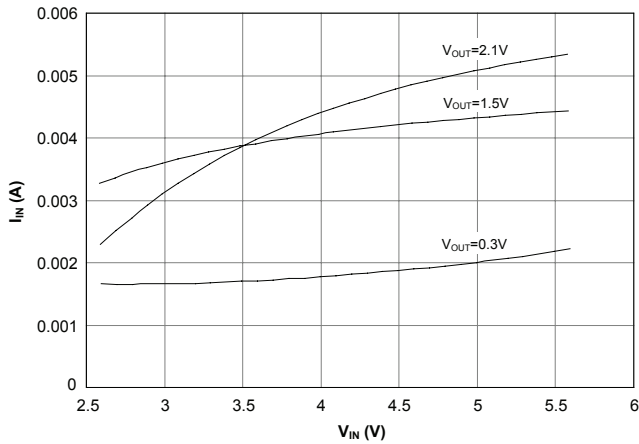
Shutdown Current vs. Temperature, V_{IN} = 3.6V
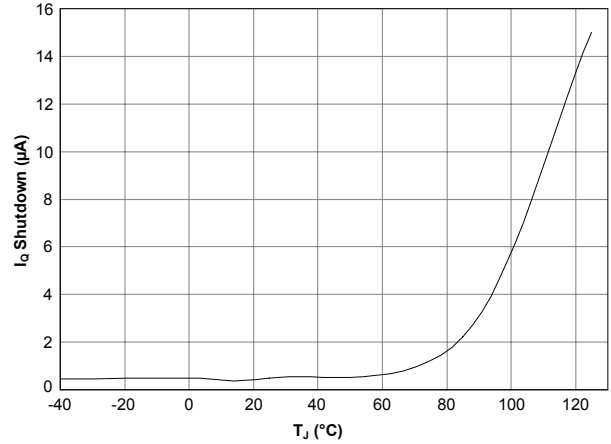
Load Regulation, V_{OUT} = 2.1V
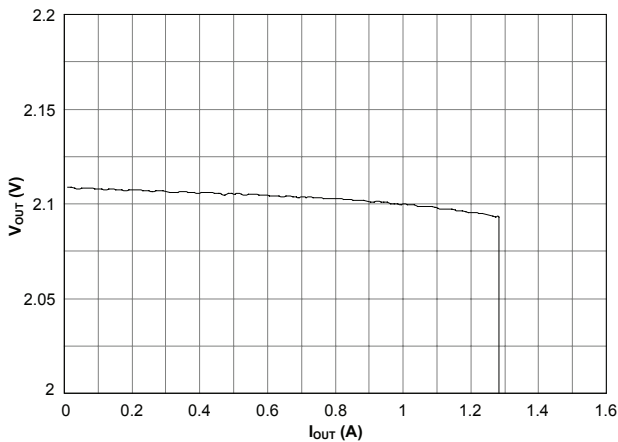
Line Regulation, V_{OUT} = 1.5V

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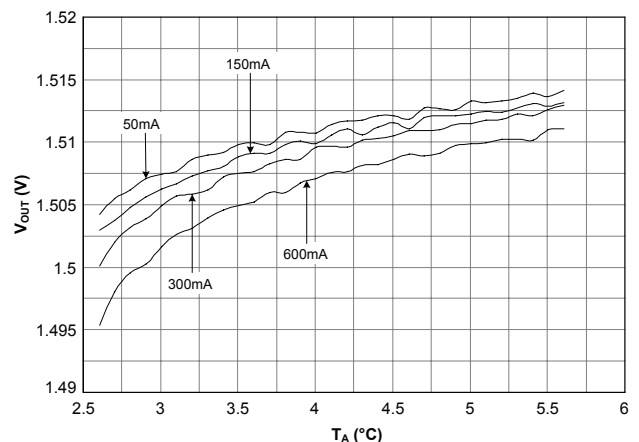
Typical Characteristics (Cont.)

V_{OUT} vs. Temperature (V_{OUT} = 1.5V)
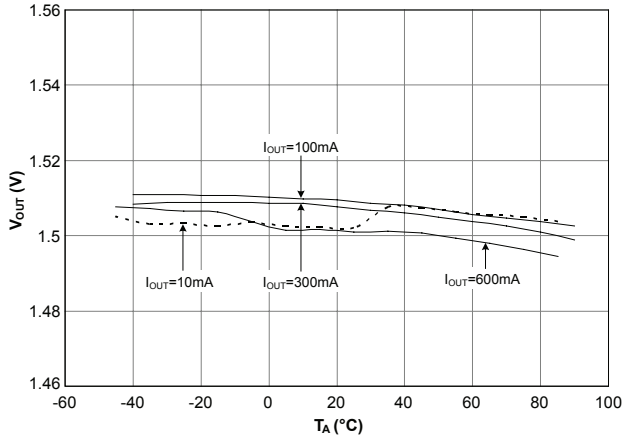
V_{OUT} vs. Temperature (V_{OUT} = 3.2V)
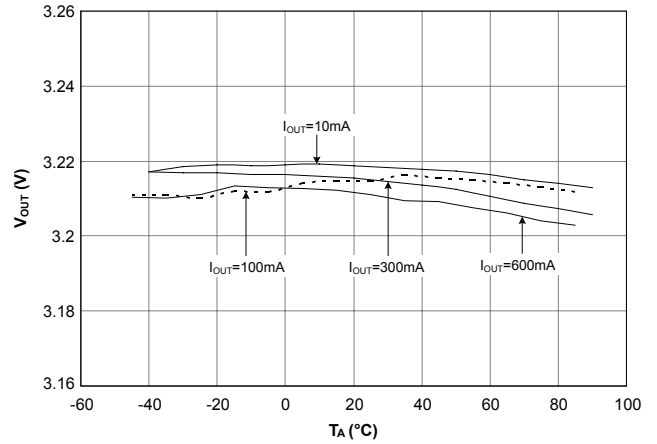
V_{REF} vs. V_{IN}
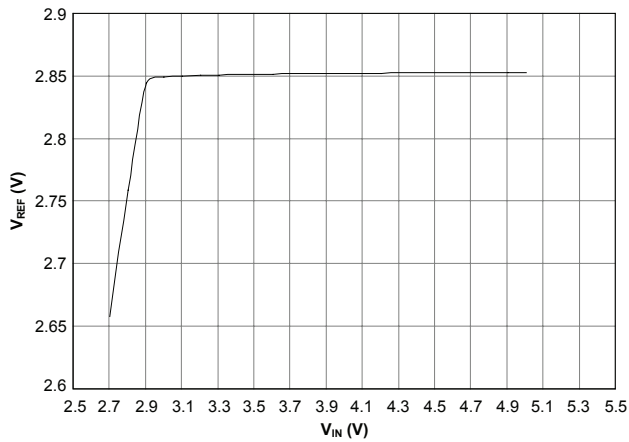
V_{REF} vs. I_{REF}
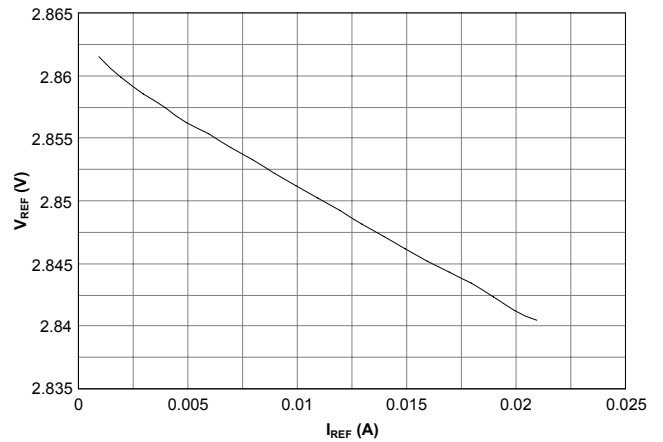
Maximum Output Current, V_{OUT} = 2.5V
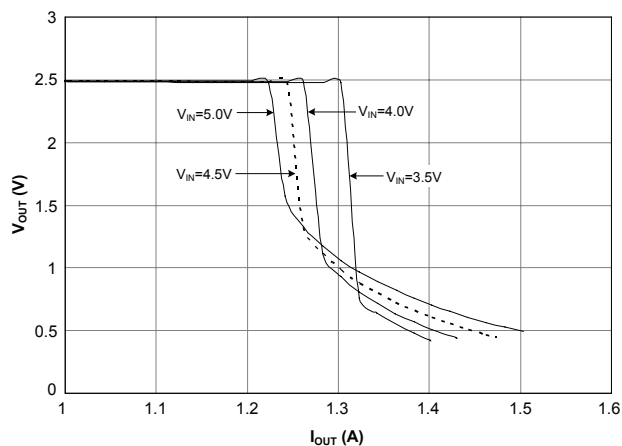
Maximum Output Current, V_{OUT} = 1.8V

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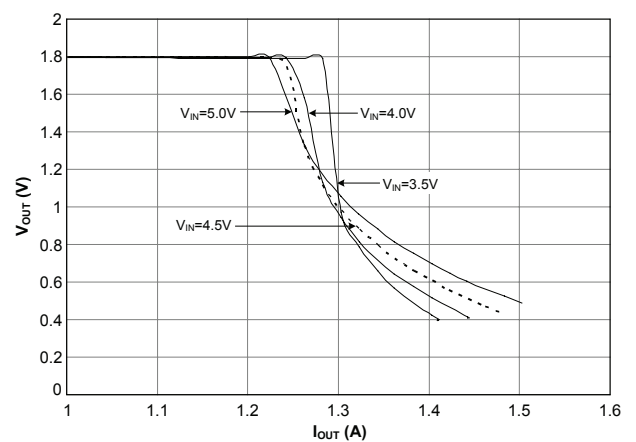
Typical Characteristics (Cont.)

Maximum Output Current, V$_{OUT}$ = 1.5V

Plot: V$_{OUT}$ (V) vs I$_{OUT}$ (A). Curves labeled V$_{IN}$=5.0V, V$_{IN}$=2.7V, V$_{IN}$=3.0V, V$_{IN}$=4.5V, V$_{IN}$=3.5V, V$_{IN}$=4.0V.
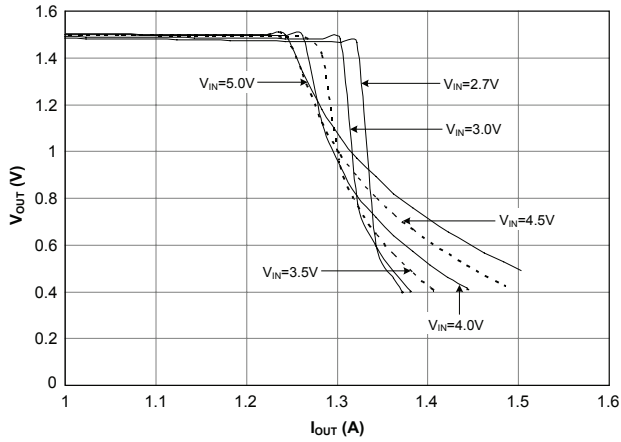
Dropout Voltage vs. Bypass Load Current
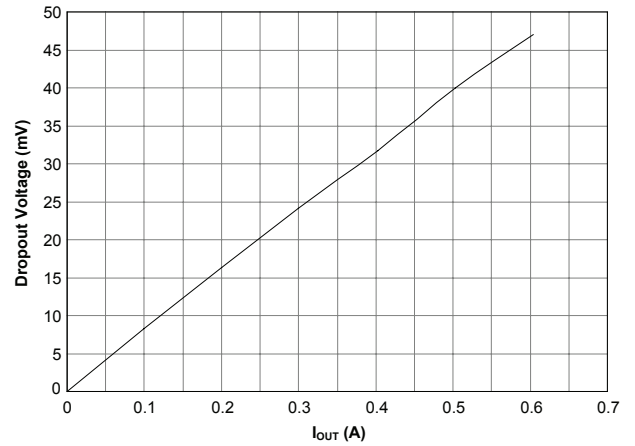
Plot: Dropout Voltage (mV) vs I$_{OUT}$ (A).

PMOS Current Limit vs. Temperature

Plot: PMOS Current Limit (mA) vs T$_J$ (°C).

Passthrough Current Limit vs. Temperature
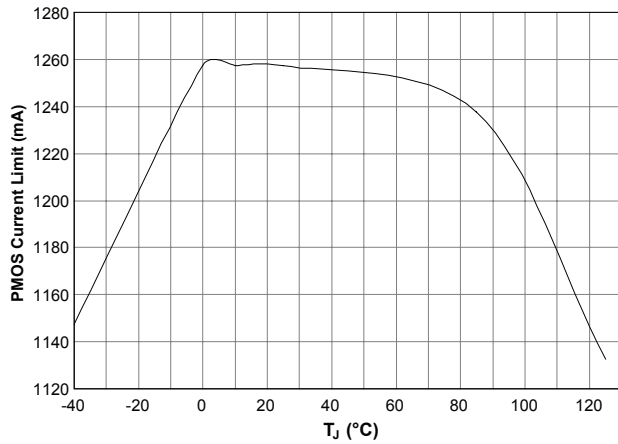
Plot: Passthrough Current Limit (mA) vs T$_J$ (°C).
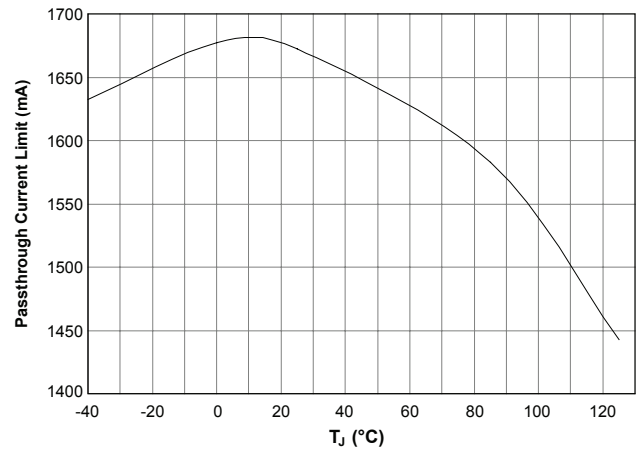
Oscillator Frequency vs. V$_{DAC}$, V$_{IN}$ = 3.6V

Plot: Switching Frequency (kHz) vs V$_{DAC}$(V).
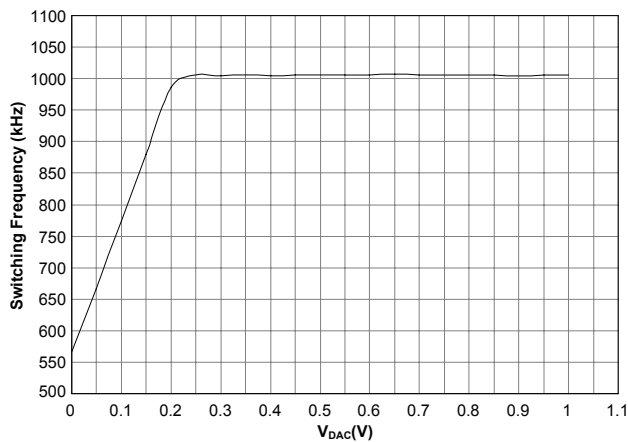
Oscillator Frequency vs. Temperature, V$_{IN}$ = 3.6V

Plot: Oscillator Frequency (kHz) vs T$_J$ (°C).

![SEMTECH logo] **SEMTECH**
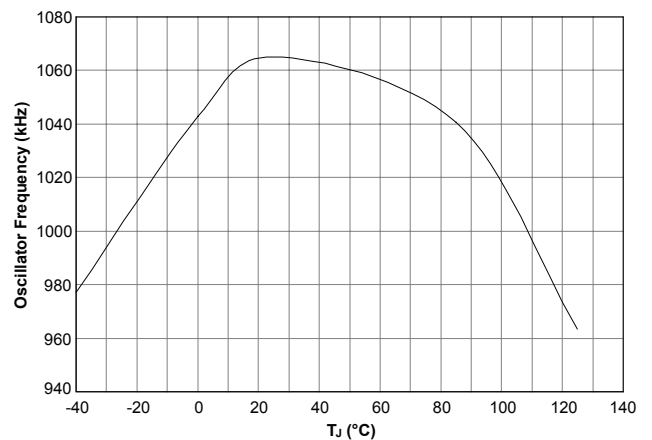
POWER MANAGEMENT

Typical Characteristics (Cont.)

R_{DSON} vs. Temperature, $V_{IN} = 3.6V$
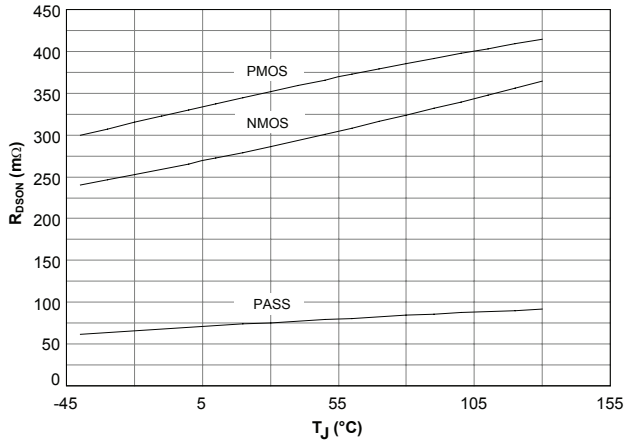
R_{DSON} vs. V_{IN}
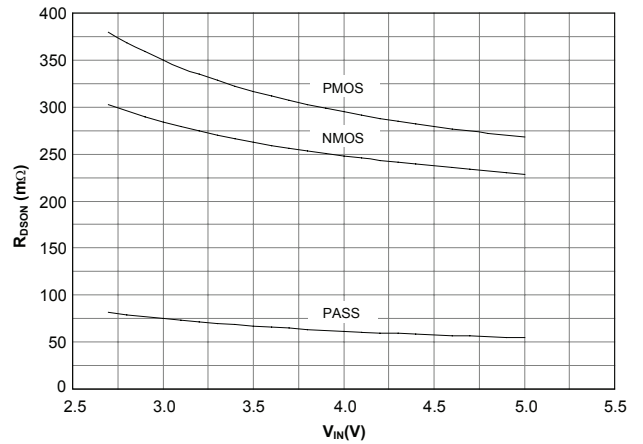
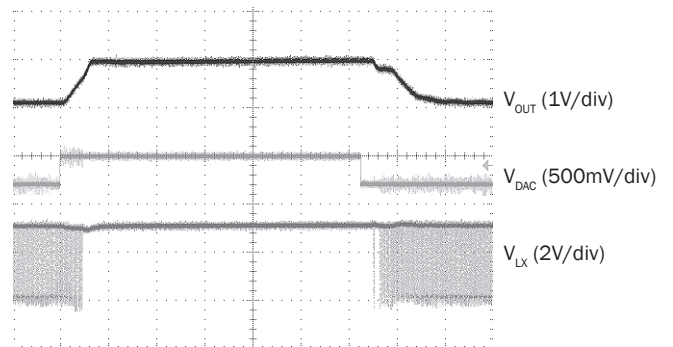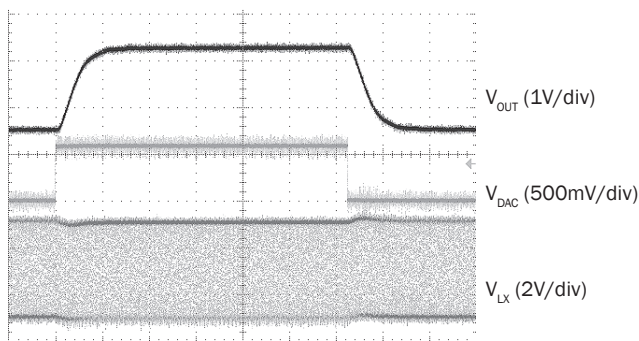### V_{DAC} Step Response (Pass-through)
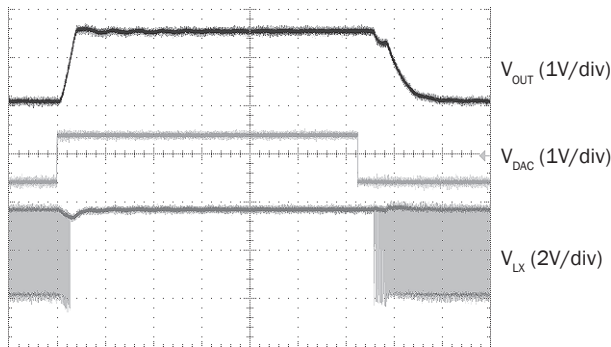
Time (40µs/div)
Condition V_{IN}=3.6V, Load=15Ω, V_{DAC}=0.7 to 1.7V
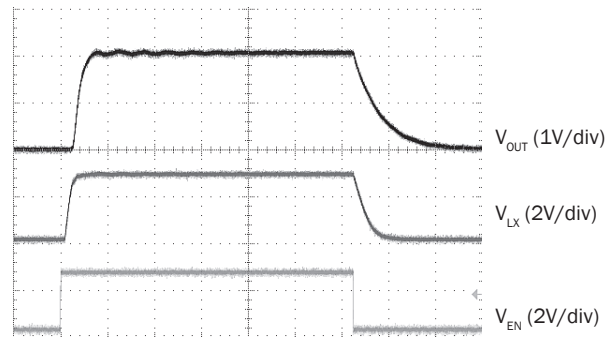
V_{DAC} Step Response (100% duty)

Time (40µs/div)
Condition V_{IN}=3V, Load=15Ω, V_{DAC}=0.7 to 1V

V_{DAC} Step Response

Time (40µs/div)
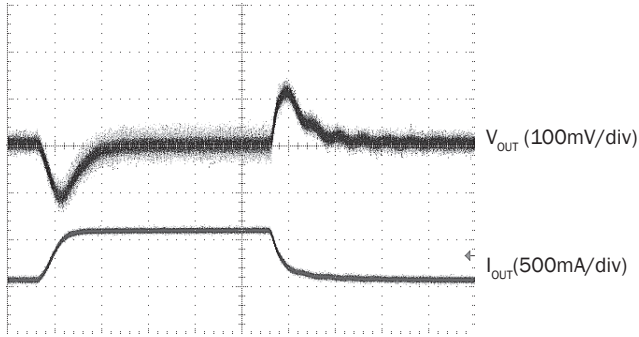Condition V_{IN}=4.2V, Load=15Ω, V_{DAC}=0.5 to 1.1V

Enable Transient

Time (40µs/div)
Condition V_{IN}=3.6V, Load=15Ω, V_{DAC}=0.7V

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Typical Characteristics (Cont.)

Load Step response (V$_{OUT}$=3.25V)

V$_{OUT}$ (100mV/div)

I$_{OUT}$(500mA/div)

Time (40µs/div)
Condition V$_{IN}$=4.2V, Load=600mA-60mA, V$_{OUT}$=3.25V

Load Step response (V$_{OUT}$=1.5V)

V$_{OUT}$ (100mV/div)

I$_{OUT}$(500mA/div)
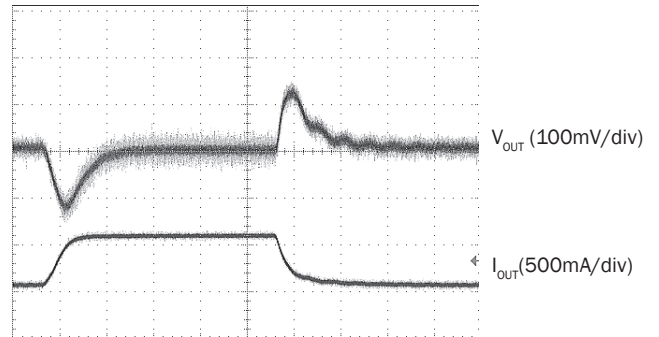
Time (40µs/div)
Condition V$_{IN}$=3.6V, Load=600mA-60mA, V$_{OUT}$=1.5V

Enable Start-Up

V$_{EN}$ (2V/div)

V$_{OUT}$ (1V/div)

V$_{LX}$ (5V/div)

I$_{IN}$ (500mA/div)
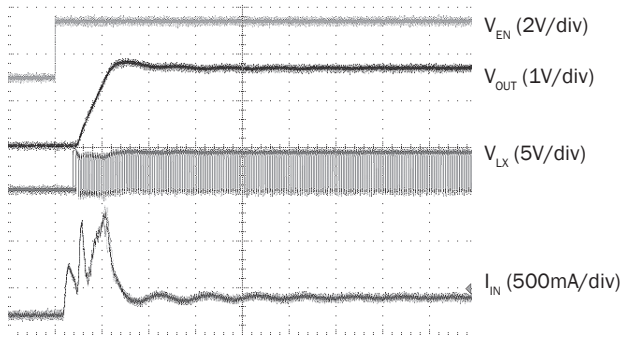
Time (20µs/div)
Condition V$_{IN}$=4.2V, Load=15Ω, V$_{OUT}$=3.4V

Output Ripple Waveform (V$_{OUT}$=3.25V)

V$_{OUT}$ (50mV/div)

V$_{LX}$(5V/div)
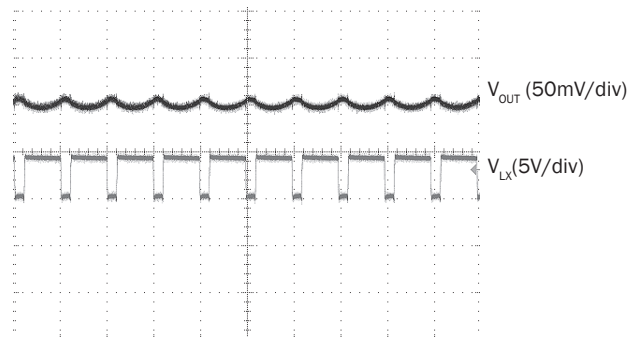
Time (1µs/div)
Condition V$_{IN}$=4.2V, Load=300mA, V$_{OUT}$=3.25V

Output Ripple Waveform (V$_{OUT}$=1.5V)

V$_{OUT}$ (50mV/div)

V$_{LX}$(5V/div)
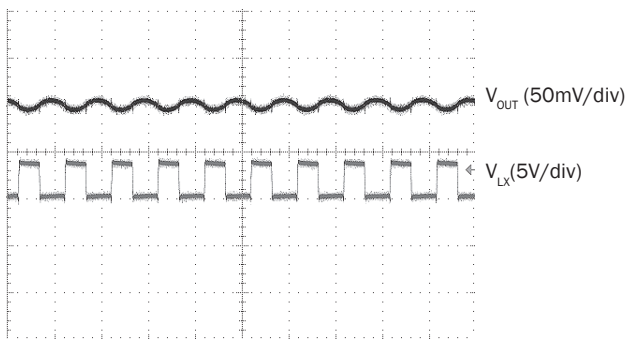
Time (1µs/div)
Condition V$_{IN}$=3.6V, Load=300mA, V$_{OUT}$=1.5V

Pass-Through Current Limit

V$_{OUT}$ (1V/div)

V$_{LX}$(2V/div)
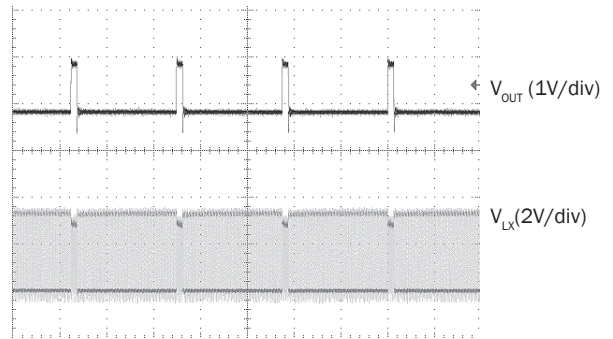
Time (1ms/div)
Condition V$_{IN}$=3.6V, Load=1Ω, V$_{DAC}$=1.4V

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POWER MANAGEMENT

Outline Drawing - MLPD-W8, 2.3 x 2.3
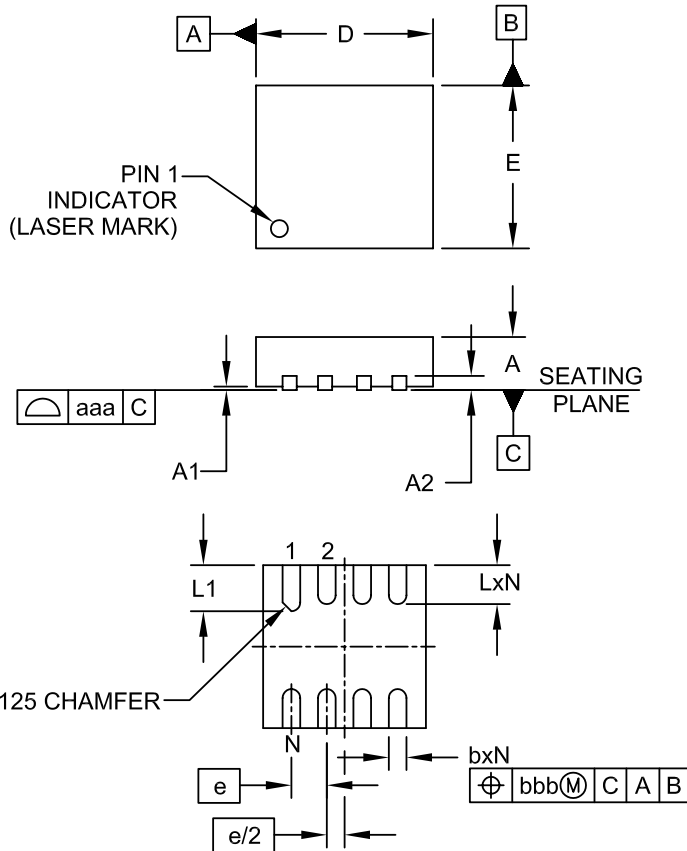
DIMENSIONS						
DIM	INCHES			MILLIMETERS		
	MIN	NOM	MAX	MIN	NOM	MAX
A	.028	.030	.031	0.70	0.75	0.80
A1	.000	.001	.002	0.00	0.02	0.05
A2		(.008)			(0.20)	
b	.008	.010	.012	0.20	0.25	0.30
D	.087	.091	.094	2.20	2.30	2.40
E	.087	.091	.094	2.20	2.30	2.40
e		.020 BSC			0.50 BSC	
L	.018	.022	.026	0.45	0.55	0.65
L1	.022	.026	.030	0.55	0.65	0.75
N		8			8	
aaa		.003			0.08	
bbb		.003			0.08	

NOTES:
1. CONTROLLING DIMENSIONS ARE IN MILLIMETERS (ANGLES IN DEGREES).

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Land Pattern - MLPD-W8, 2.3 x 2.3
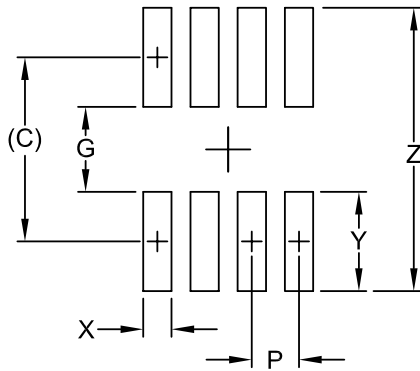
DIMENSIONS		
DIM	INCHES	MILLIMETERS
C	(.077)	(1.95)
G	.035	0.90
P	.020	0.50
X	.012	0.30
Y	.041	1.05
Z	.118	3.00

NOTES:

1. THIS LAND PATTERN IS FOR REFERENCE PURPOSES ONLY.
CONSULT YOUR MANUFACTURING GROUP TO ENSURE YOUR
COMPANY'S MANUFACTURING GUIDELINES ARE MET.

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